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ORGANOCHLORINES AND TRACE ELEMENTS IN AVIAN PREY OF PEREGRINE FALCONS IN COLORADO: TEN YEARS AFTER

FIRST YEAR INTERMIN REPORT OF A TWO YEAR STUDY

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ABSTRACT

Bird species considered potential prey for peregrine falcons were collected at 10 sites in Colorado for analysis of organochlorine (OC) compounds and trace elements (TE). Migratory and non-migratory species representing insectivorous and omnivorous feeding habits were selected. Composite samples (7 individuals/sample) of whole bodies excluding the gastrointestinal tract were analyzed for organochlorine compounds and composite liver samples (5 livers/sample) were analyzed for TEs.

Of 22 different OC compounds, Dichlorodiphenyldichlorethylene (DDE) occurred most frequently (100%) and at the highest concentrations. None of the other OC compounds occurred frequently or at significant concentrations. Migratory species contained higher concentrations of DDE (Geometric Mean (GM)=0.75 ppm) than non-migratory species (GM=0.22 ppm) and insectivorous species (GM=1.44 ppm) were generally more contaminated than omnivorous species (GM=0.14 ppm). When compared to the results of an identical study done in 1980, DDE concentrations in migratory species declined by 2X but increased by 3X in non-migratory species and concentrations declined in both insectivorous and omnivorous species. The mean DDE concentration (0.62 ppm) over all species collected is less than the dietary level of 3 ppm DDE found to be harmful in other raptor species.

Of 22 different TEs, only mercury and selenium occurred at concentrations of concern, both occurring in 100% of the samples collected. Swallow species and killdeer (migratory insectivores) contained the highest concentrations of mercury and selenium. The

mean mercury concentration (GM=0.19) over all species collected is at lower end of the range of mercury concentrations considered to cause reproductive effects in some birds (0.176-0.352). The mean selenium concentration in liver samples (9.52 ppm) is above the dietary concentration of 5 ppm selenium considered harmful to waterfowl and other birds. Potential TE dietary exposure (from consumption of whole birds) for peregrine falcons is unclear based on liver sample data reported here.

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INTRODUCTION

Widespread use of the pesticide dichlorodiphenyltrichloroethane (DDT) in the United States during the late 1940s, 1950s, and 1960s led to increased eggshell thinning in avian predators resulting from the contamination of DDT and metabolites in their prey. By the mid 1960's, substantial declines in populations of the peregrine falcon (_Falco peregrinus_) were noted in the northern hemisphere (Hickey 1969). By the late 1970s, populations in the northern Rocky Mountain states, including Colorado, had for the most part disappeared (Enderson et al. 1982). As a result of a 1972 nationwide ban on the use of DDT in the United States and intensive recovery efforts, peregrine falcon populations began to return to the central and northern Rocky Mountains. Populations in western Colorado are currently approaching recovery goals. Despite the success of these efforts, peregrine falcons in some parts of Colorado and other Rocky Mountain areas continue to experience significant eggshell thinning.

While peregrine falcons may accumulate DDT or its metabolites (mainly DDE) from prey items on their wintering grounds, the major source may be migrant prey available near peregrine eyries in summer (Enderson et al. 1982). The principal prey of peregrine falcons are small to medium-sized birds. In the late 1970's, several studies documented significant levels of DDE and other organochlorines (OCs) in avian prey near historical and active eyries in Colorado and New Mexico (Enderson et al. 1982). In 1980, the U.S. Fish and Wildlife Service (Service) also reported OCs in Passeriformes and other avian prey of peregrine falcons collected near existing eyries in eight western states, including Colorado (DeWeese et al. 1986). The present study was initiated to repeat the 1980 Service study (DeWeese et al. 1986). The study was designed to enable a comparison of the change in concentrations of DDT+metabolites and other OCs in prey species during the ten year period. This study also established baseline data for trace element (TEs) concentrations in the same prey base which have not been previously reported. This interim report presents the results of prey collections and sample analysis in 1989. Additional samples collected in 1990 will be combined with the present data and presented in a final report in 1991. Companion studies were also conducted in Utah, Montana and Wyoming in 1989 and 1990.

STUDY AREA

Peregrine falcons have historically nested in Colorado along the east and west slopes of the Rocky Mountains (Enderson et al. 1982). The following criteria, in order of priority, were used to determine peregrine prey sample collection sites within the state: 1) site of historical collections and existing data base, 2) known or suspected existence of breeding peregrines, 3) planned peregrine hacking site, and 4) potential peregrine habitat that lies geographically removed from other collection sites. Based on these criteria, 10 sampling sites were identified for Colorado which occur in the northern and southern ends of the state and east and west of the Continental Divide (fig. 1). Samples were obtained, in most cases, within 15 miles of these sites to reflect the prey that would be available to peregrines if they were nesting at the sites.

METHODS

Five species of birds considered potential peregrine prey or their corresponding alternates (based on Enderson et al. 1982) were targeted for collection at each site (table 1). Migratory and non-migratory species representing insectivorous and omnivorous feeding habits were selected so that comparisons could be made between groups (table 2). Twelve individuals of each of the five species were to be collected from within 15 miles of an existing or historical eyrie. However, a full sample of all 12 individuals of each species was not always obtained from each site and many of the targeted samples were not obtained until 1990. To avoid inherent variation in contaminant concentrations caused by age, only adult individuals were collected. Because all species are not sexually dimorphic, males or females were not differentially chosen for collection. Birds were collected with a shotgun using steel shot during the period April-June 1989, before most young-of-the-year had fledged.

Individual whole birds collected for OC analysis were wrapped in aluminum foil, labeled and placed in a plastic bag. Individual whole birds collected for TE analysis were placed in plastic bags and labeled. All birds were frozen by placing them on dry ice within a few hours of collection. The samples were then

Figure 1. Sampling sites for bird species collected in Colorado, 1989

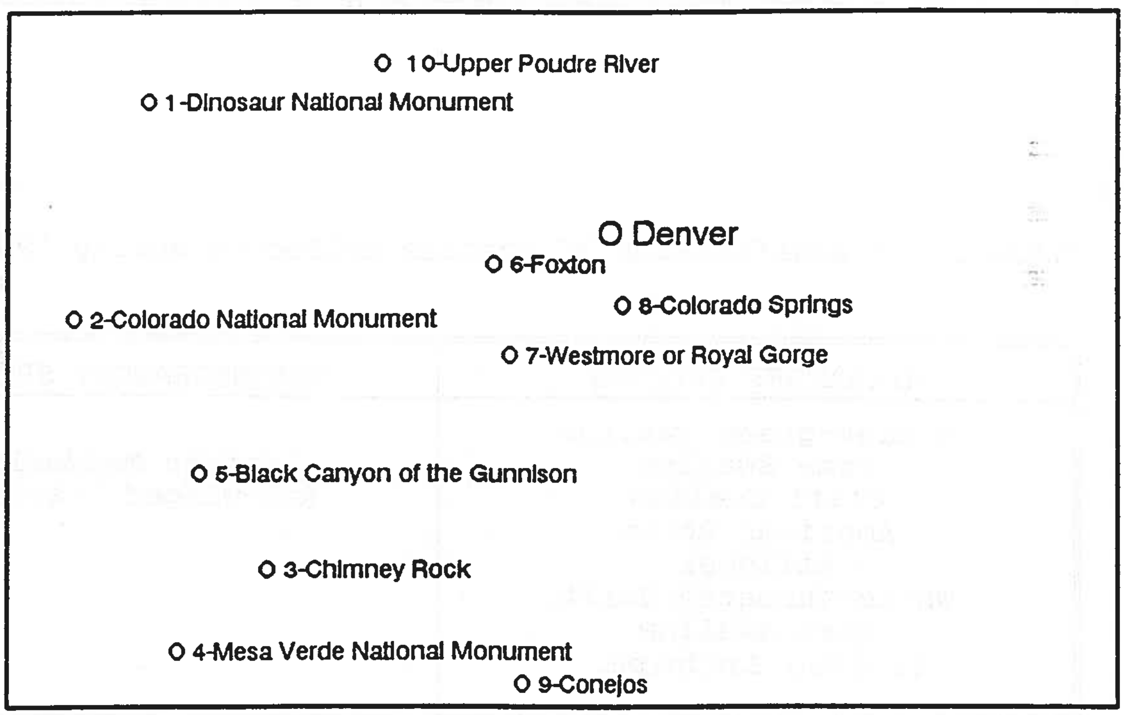


Table 1. Bird species collected at each site and their corresponding alternates

SPECIES COMMON NAME	ALTERNATE (in order of preference)
Tree Swallow (TS)	Cliff Swallow (CS) Violet-green Swallow (VG) Barn Swallow (BS)
Killdeer (KD)	Spotted Sandpiper (SS)
Brewer's Blackbird (BB)	American Robin (AR) Red-winged Blackbird (RB)
White-throated Swift (WS)	Cliff Swallow (CS) Violet-green Swallow (VG) Barn Swallow (BS)
Western Meadowlark (WM)	Horned Lark (HL)

Table 2. Classification of species collected during 1980 and 1989

MIGRATORY SPECIES	NON-MIGRATORY SPECIES
Violet-green Swallow Tree Swallow Cliff Swallow American Robin Killdeer White-throated Swift Barn Swallow Spotted Sandpiper	Western Meadowlark Red-winged Blackbird
INSECTIVEROUS SPECIES	**OMNIVEROUS SPECIES**
Violet-green Swallow Tree Swallow Cliff Swallow Killdeer White-throated Swift Barn Swallow Spotted Sandpiper	American Robin Western Meadowlark Red-winged Blackbird

transported to a freezer where they remained frozen until processed.

When a full sample of twelve individuals was available from a site, seven of these were combined to form a single composite of whole birds for OC analysis. Whole livers from the five remaining individuals were combined to form a single composite sample for TE analysis. Thus, twelve individuals of each species from each site were split to form two composite samples: one of whole birds for OCs and one of livers for TEs. When less than 12 individuals of a species was obtained, an OC sample was prepared as above with a minimum of 5 whole birds. A TE sample was also prepared if a minimum of 3 livers were available. Composite samples were not prepared with less than the minimum number of whole birds or livers. Samples were processed at the Service's Colorado Field Office laboratory in Golden, Colorado. For OC analysis, each bird was prepared as described by Enderson et al. (1982) by removing the feathers by hand plucking followed by removal of the beak, tarsi, and gastrointestinal tract. Sex of the individuals was confirmed by examination of internal organs. The prepared whole bird was wrapped in aluminum foil, labeled and frozen. For TE analysis, livers were removed with forceps and scalpel and placed in a chemically-clean glass jar fitted with a teflon-lined lid. After preparation and dissection, samples were refrozen and shipped to an analytical laboratory. Organochlorine samples were analyzed at Mississippi State Chemical Laboratory, Mississippi State, Mississippi and samples for TE analysis were analyzed at Research

Triangle Institute, Research Triangle Park, North Carolina (for analytical methods and Quality Assurance/Quality Control report see Appendix A).

RESULTS AND DISCUSSION

Organochlorines (OCs)

Because sufficient samples were not available at each site to meet the minimum requirements for compositing, only 25 composite samples from 8 sites were analyzed for OCs (table 3). Concentrations for all OCs are reported in parts per million (ppm=mg/kg), fresh weight (FW) and all computed means are geometric means.

Composite samples were analyzed for 22 different OC compounds. The lower limit of detection (LLOD) for samples analyzed in this study was 0.05 ppm for toxaphene and PCB's and 0.01 ppm for all other OC compounds. Eleven compounds occurred in at least one sample and 11 did not occur in any samples (Appendix B). DDE occurred in samples most frequently (100%) followed by oxychlordane (52%) and heptachlor epoxide and Beta-BHC (44%) (table 4). Means were computed for those compounds which occurred at 10X the LLOD in greater than 50% of the samples (only DDE occurred at this concentration and frequency). None of the samples contained each of the 11 OCs and only 7 samples contained 6 or more. With the exception of DDE, all OCs occurred at or just above the LLOD (Appendix B). Concentrations which are less than 10X the LLOD are

Table 3. Total number of composite samples for organochlorine and trace element analysis collected at each site during 1989

SITE #/LOCATION	TYPE OF ANALYSIS	
	Organochlorine	Trace Element
1) Dinosaur National Monument	5	5
2) Colorado National Monument	6	5
3) Chimney Rock	0	1
4) Mesa Verde National Monument	4	2
5) Black Canyon of the Gunnison National Monument	3	1
6) Foxton	1	1
7) Wetmore or Royal Gorge	1	0
8) Colorado Springs	2	0
9) Conejos	0	0
10) Upper Poudre River	3	1

Table 4. Percent occurrence of organochlorines in composite samples collected from Colorado in 1989 and 1980

COMPOUND	PERCENT OCCURRENCE		
	1989 (N=25)	1989* (N=25)	1980 (N=21)
p',p'-DDE	100	88	95
Oxychlordane	52	04	19
Alpha-BHC	08	00	29
Beta-BHC	44	05	29
Heptachlor Epoxide	44	08	19
Dieldrin	40	04	ND
PCB's (total)	36	36	52
Hexa. Chloro. Benzene	12	00	05
Mirex	08	08	<10
t-Nonachlor	24	00	<5

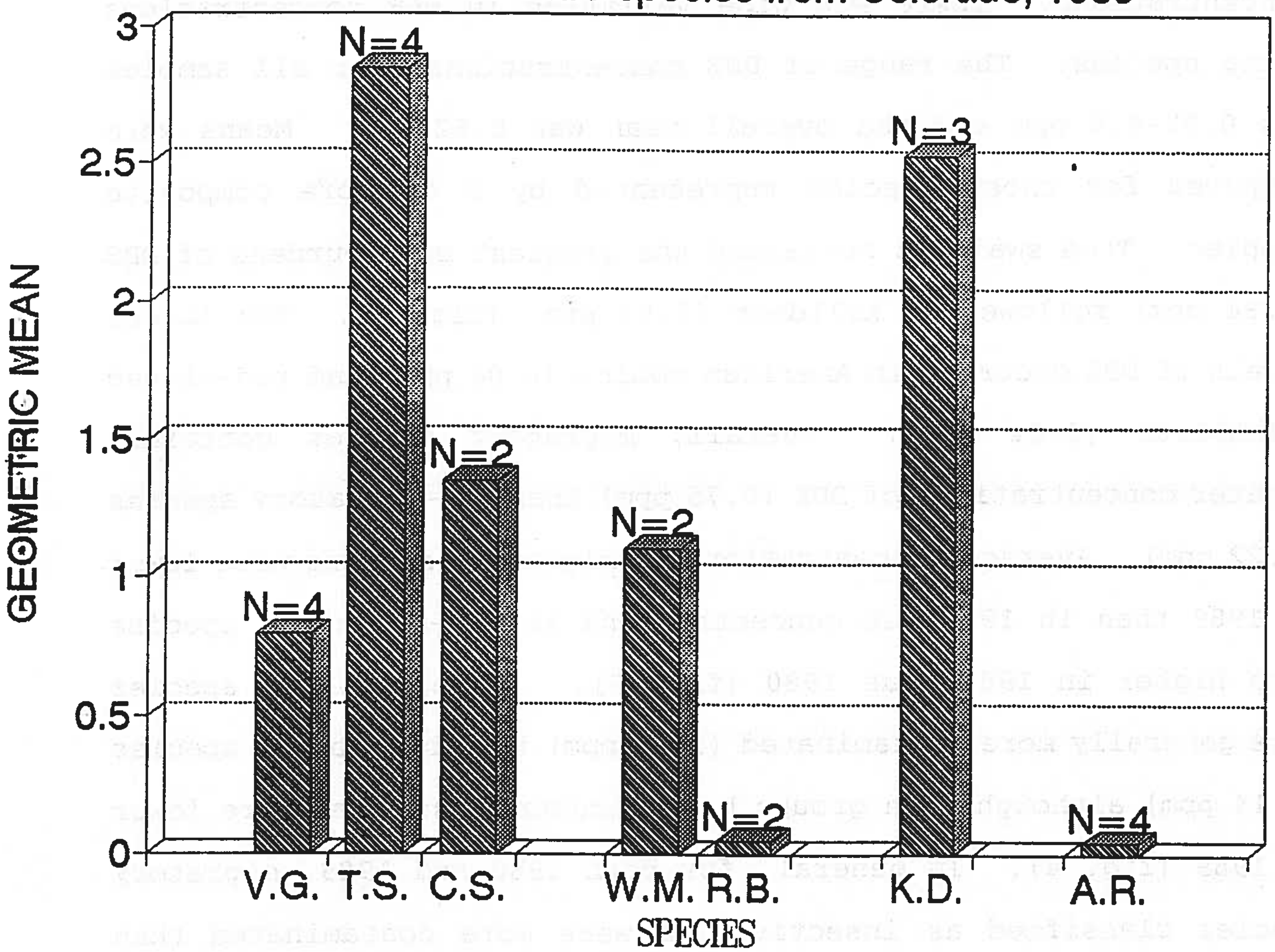
* Based on the lower limit of detection established for 1980 analysis: 0.10 ppm for PCB's and toxaphene and 0.05 ppm for other organochlorines.

within the limits for natural variation or instrument "noise" and may not be significant.

DDE--DDE was the most prevalent OC and occurred at the highest concentrations. There was wide variation in DDE concentrations among species. The range of DDE concentrations over all samples was 0.02-4.6 ppm and the overall mean was 0.62 ppm. Means were computed for those species represented by 2 or more composite samples. Tree swallows contained the greatest body burdens of DDE (2.84 ppm) followed by killdeer (2.53 ppm) (fig. 2). The lowest levels of DDE occurred in American robins (0.04 ppm) and red-winged blackbirds (0.04 ppm). Overall, migratory species contained greater concentrations of DDE (0.75 ppm) than non-migratory species (0.22 ppm). Average concentrations in migratory species were lower in 1989 than in 1980 but concentrations in non-migratory species were higher in 1989 than 1980 (fig. 3). Insectivorous species were generally more contaminated (1.44 ppm) than omnivorous species (0.14 ppm) although both groups had concentrations that were lower in 1989 (fig. 4). In general, for both 1980 and 1989, migratory species classified as insectivorous were more contaminated than migratory species classified as omnivorous. However, concentrations in both groups declined from 1980 to 1989 (fig. 5).

The LLOD reported for the 1980 samples (0.10 ppm for PCBs and toxaphene and 0.05 for all other OCs) was slightly higher than that reported for the 1989 samples . Based on the 1980 LLOD, only one compound, DDE, occurred in greater than 10% of the 1989 samples

Figure 2. DDE concentrations in composite whole body samples of selected bird species from Colorado, 1989



V.G. = Violet-green Swallow
T.S. = Tree Swallow
C.S. = Cliff Swallow
W.M. = Western Meadowlark
R.B. = Red-winged Blackbird
K.D. = Killdeer
A.R. = American Robin

Figure 3. DDE concentrations in composite whole body samples of migratory and non-migratory bird species from Colorado

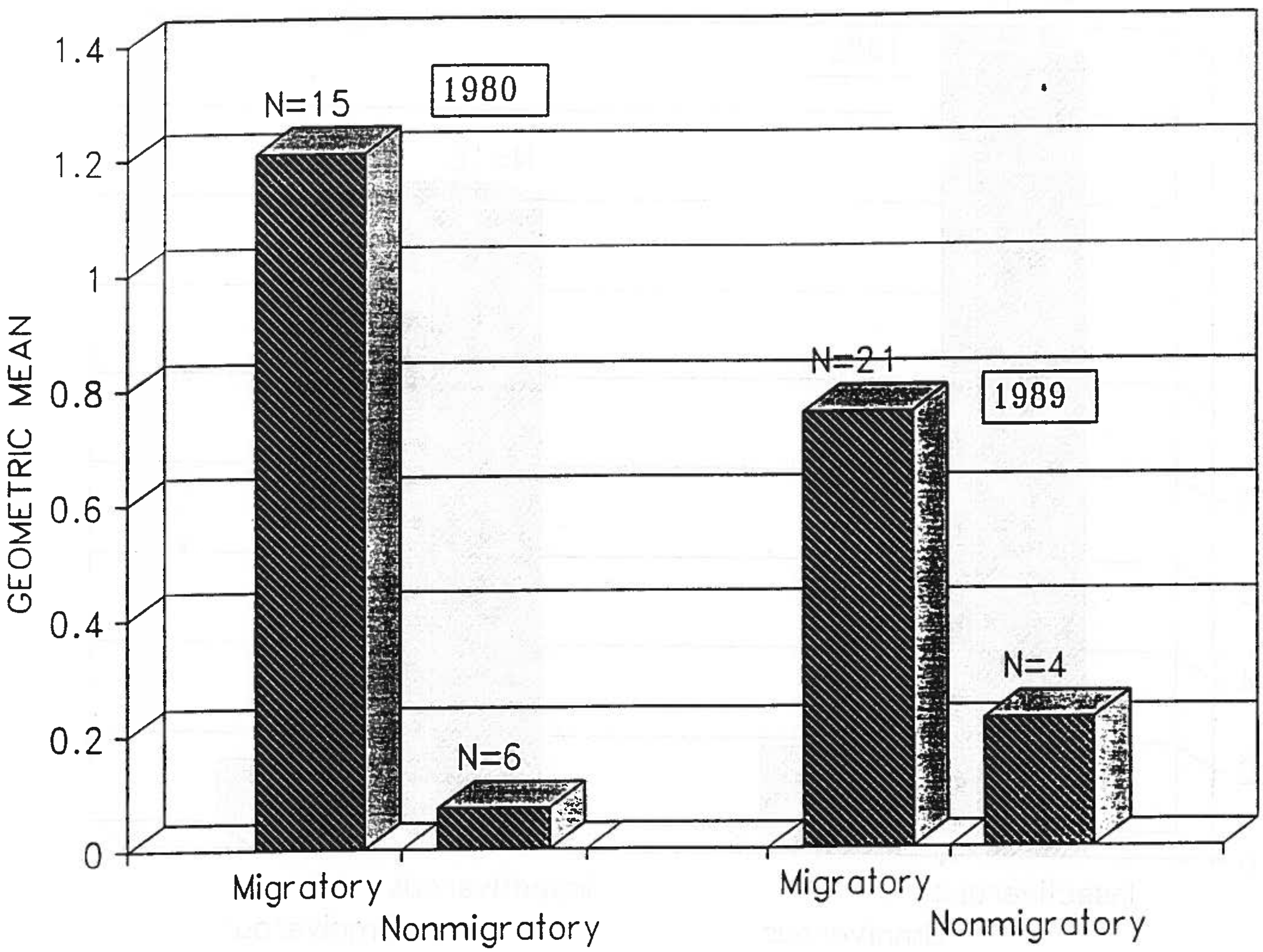


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Figure 4. DDE concentrations in composite samples of insectiverous and omniverous species collected in Colorado

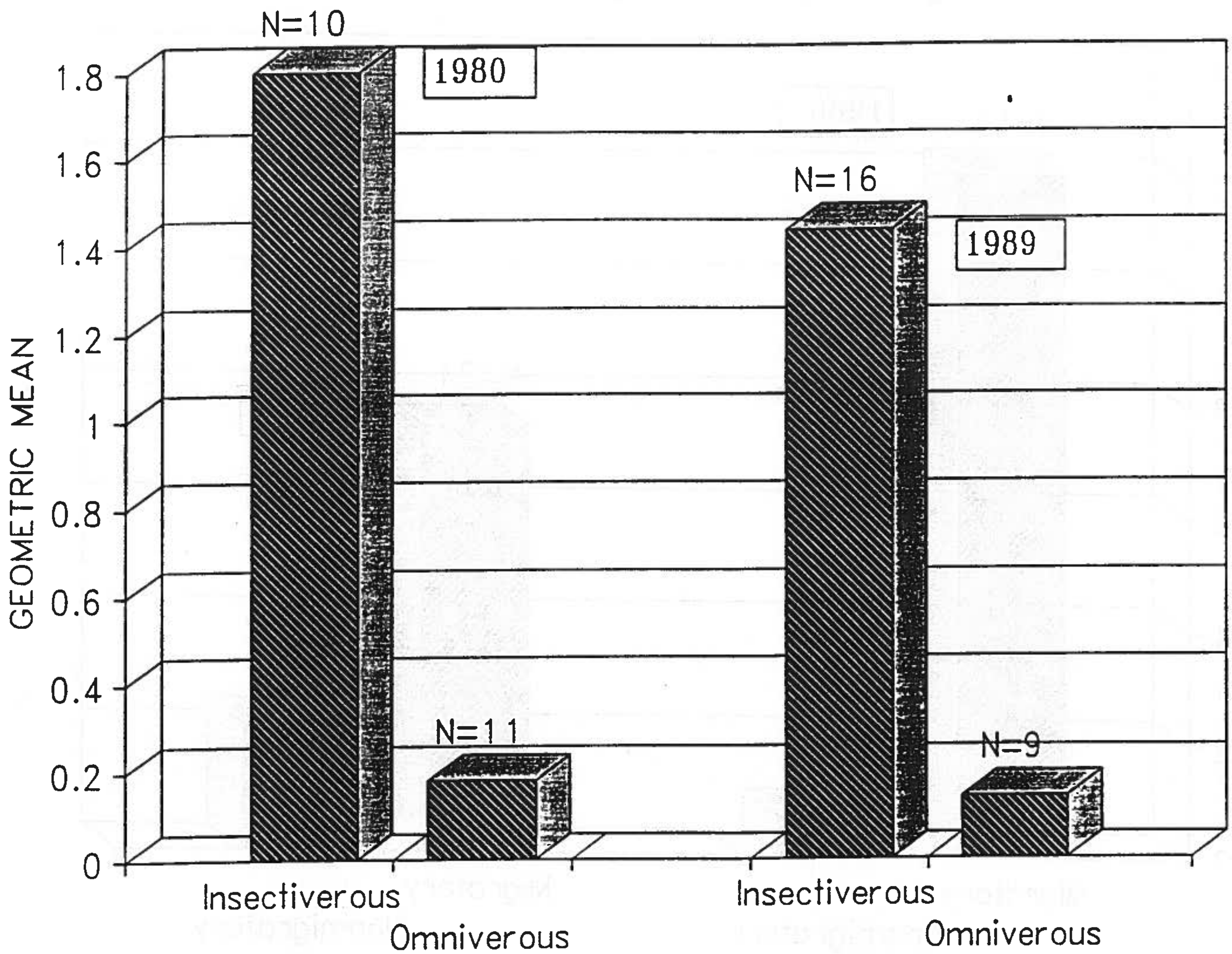
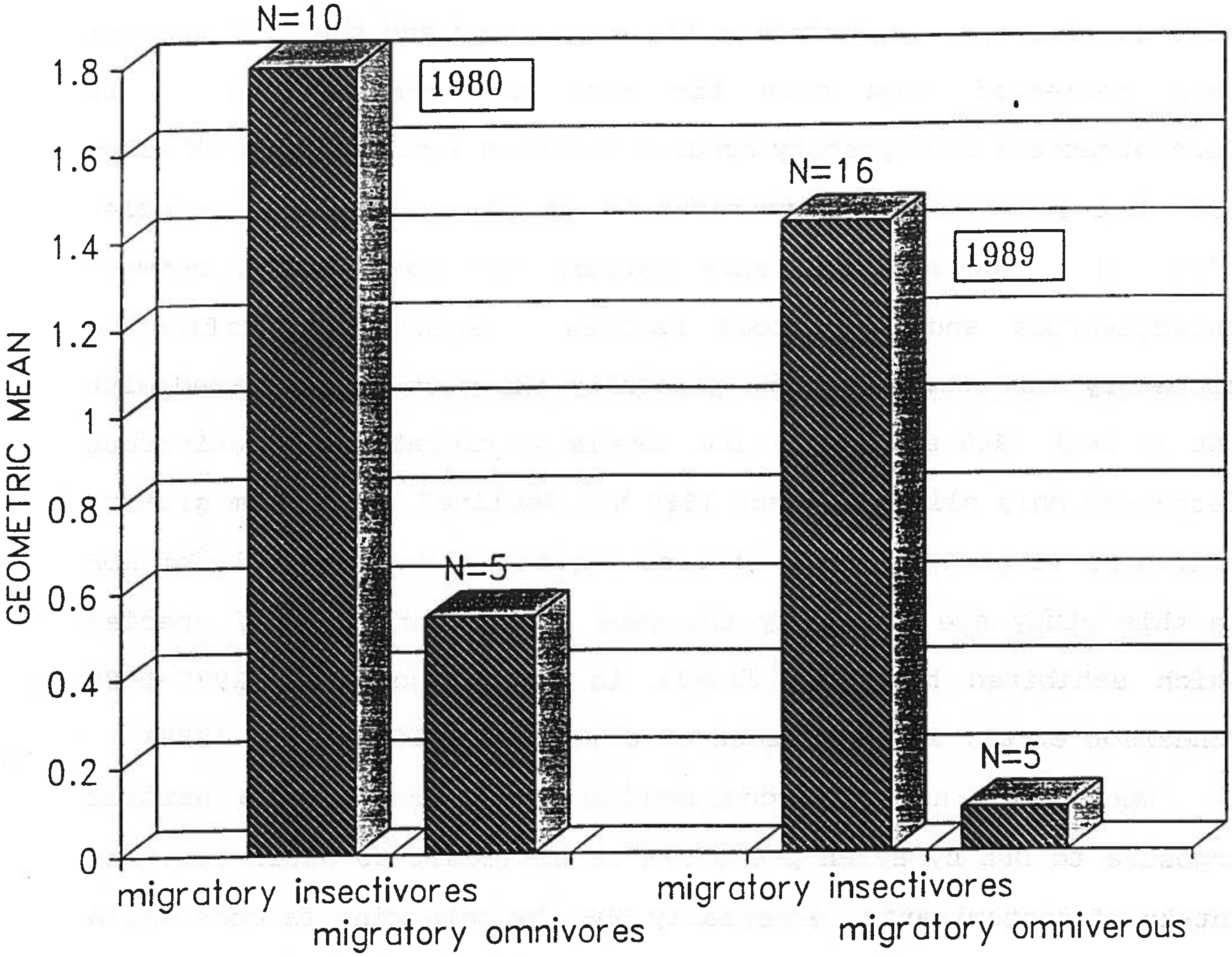


Figure 5. DDE concentrations in composite whole body samples of migratory insectivorous and omnivorous bird species from Colorado



compared to 1980 when 6 compounds occurred in greater than 10% of the samples (table 4). In 1980, the range of DDE concentrations reported was 0.03-11.10 ppm compared to 0.02-4.6 ppm in 1989.

DDE residues in Violet-green swallows collected on the west slope of the Rocky Mountains decreased by 9X from 1980 to 1989. A similar decrease (10X) was evident in American robins, however, the 1980 samples were collected on the west slope and the 1989 samples were collected from both the east and west slopes. DDE concentrations in migratory species declined approximately 2X since 1980 but increased by approximately 3X in non-migratory species (fig. 3). However, the same pattern was not evident between insectivorous and omnivorous species. Species classified as migratory insectivorous were generally the most contaminated with DDE in both 1980 and 1989. DDE levels in migratory insectivorous decreased only slightly since 1980 but declined by 5X in migratory omnivores (fig. 5). Those species showing elevated levels of DDE in this study are generally the same species or class of species which exhibited high DDE levels in surveys done in 1977-1980 (Enderson et al. 1982, DeWeese et al. 1986, Ellis et al. 1989)

Whether or not prey consumption would result in a harmful exposure to DDE by avian predators is difficult to determine. The intake of contaminants, especially DDE, by peregrine falcons would depend on the prey species taken by individual peregrines. If the species examined in this study are representative of the diets of peregrine falcons in Colorado, then the mean DDE concentration (0.62 ppm) over all species collected may be representative of potential exposure. In several raptor species a dietary level of about 3 ppm DDE FW led to thinned eggshells by 10-20% and adversely affected reproduction (Mendenhall et al. 1983; Lincer 1975; McLane et al. 1972; and, Weimeyer et al. 1970). Assuming peregrine falcons respond similarly, then on average, none of the prey species collected in this study alone or combined with others represents a significant DDE threat to peregrines. However, this does not consider length of exposure which could affect the significance of exposure.

OTHER OC's Ten compounds besides DDE were also detected but only mirex occurred at concentrations greater than or equal to 10 times the LLOD. However, mirex occurred in only 2 (8%) of the samples and in these samples it occurred equal to and just above 10X the LLOD. None of the other OC's were represented at a high enough frequency or in significant concentrations to warrant concern.

Trace Elements (TEs)

Composite liver sample were analyzed for 22 different TEs. All TEs with the exception of silver, cobalt, nickel, tin, and vanadium were present in greater than 10% of all samples and 13 TEs were present in greater than 50% of the samples analyzed (Appendix C). Because these samples were liver samples only and not whole birds, the potential exposure of TEs to avian predators such as peregrine falcons is difficult to determine. In general, TE residues occur at higher concentrations in liver than in whole body samples. Also, little data exists which documents harmful dietary levels of TEs to avian predators. However, general guidelines relative to health of the prey and relative to the avian diet exist for some of the TEs detected and they are discussed. Concentrations of all TEs are presented as ppm dry weight (DW) and all computed means are geometric means unless otherwise noted.

Boron--Boron occurred in 100% of the samples ranging from 0.75-3.30 ppm DW (table 5). The mean boron concentration over all species was 1.36 ppm DW. Dietary levels of 100 ppm boron FW resulted in reduced growth of female mallard ducklings (Hoffman et al. 1990). However, very little is known about the secondary effects of boron on raptor species.

Cadmium--Cadmium occurred in 100% of the liver samples from 0.40-3.41 ppm with a mean cadmium concentration of 1.42 ppm (table 5). Cadmium residues in the liver that exceed 10.0 ppm FW (approximately 35 ppm DW) should be viewed as moderately contaminated (Eisler 1985). Elevated levels of 13.0-15.0 ppm tissue FW (45.76-52.8 DW) are potentially hazardous to animals of higher trophic levels (Eisler 1985). Residues of 200 ppm FW kidney (approximately 700 ppm DW) or more than 5.0 ppm whole animal FW (approximately 17.6 ppm DW) should be considered life threatening to the organism (Eisler 1985).

Chromium--Chromium occurred in 62.5% of the liver samples ranging from 0.250-1.340 ppm DW with a geometric mean of 0.49 ppm DW (table 5). Available evidence suggests that organs and tissues that contain greater than 4.0 ppm total chromium DW should be viewed as presumptive evidence of Chromium contamination (Eisler 1986). In

Table 5. Summary of trace element concentrations for liver samples from all species for each element (mg/kg dry weight)

Element	Al	As	Ba	Be	B	Cd
Maximum	18.400	1.290	0.500	0.057	3.300	3.410
Minimum	0.000	0.000	0.000	0.000	0.752	0.405
Arithmetic Mean	0.000	0.000	0.000	0.000	1.445	1.594
Geometric Mean	0.00	0.00	0.00	0.00	1.36	1.42
% Occurrence	37.5%	18.8%	43.8%	12.5%	100.0%	100.0%
N=16						

Element	Cr	Cu	Fe	Mg	Mn	Hg
Maximum	1.340	25.200	2990.000	943.000	15.500	0.898
Minimum	0.250	18.100	650.000	705.000	3.730	0.010
Arithmetic Mean	0.562	21.388	1120.813	845.188	7.295	0.294
Geometric Mean	0.49	21.29	1011.12	842.28	6.63	0.19
% Occurrence	62.5%	100.0%	100.0%	100.0%	100.0%	93.8%
N=16						

Element	Mo	Pb	Se	Sr	Zn
Maximum	5.150	1.280	19.600	0.915	98.100
Minimum	1.620	0.100	3.700	0.150	64.900
Arithmetic Mean	3.012	0.456	11.221	0.345	84.081
Geometric Mean	2.91	0.35	9.52	0.27	83.64
% Occurrence	1.000	0.813	1.000	0.500	1.000
N=16					

another study, dietary levels of 10.0 pm Cr+3 adversely affected black ducks.

Lead--Lead occurred in 81.3% of the liver samples ranging from 0.100-1.28 ppm DW (table 5). The mean lead concentration was 0.350 ppm DW. Median liver residue in red-winged blackbirds administered a lethal dietary dose of lead acetate was 20 ppm FW (approximately 70.0 ppm DW) (Eisler 1985). Greater than 2 ppm FW (approximately 7.0 ppm DW) is considered elevated in liver of waterfowl (Eisler 1985).

Mercury--Mercury occurred in 100% of the liver samples ranging from 0.010-0.898 ppm DW with a geometric mean of 0.19 ppm DW (table 5). Categories of species that had the highest mercury concentration in livers were either insectivorous or migrants (figs. 6). Among all species collected, swallows and killdeer had the highest mercury concentrations (fig. 7). Mercury residues in seed-eating songbirds from areas with mercury-treated seed dressing averaged 1.6 ppm DW (arithmetic mean) compared to a mean of 0.03 ppm DW (arithmetic mean) in songbirds from an untreated area (Eisler 1987). Concentrations of 4.00-40.00 ppm mercury in the diet are considered lethal (Eisler 1987). For some birds, reproductive effects have been associated with 0.05-0.10 ppm FW (approximately 0.176-0.352 ppm DW) in the diet (Eisler 1987). The mean mercury concentration in the prey livers is at the lower end of this range.

Molybdenum--Molybdenum occurred in 100% of the liver samples ranging from 1.620-5.150 ppm DW with a mean of 2.91 ppm DW (table

Figure 6. Mercury concentrations in liver samples of two classes of bird species from Colorado, 1989

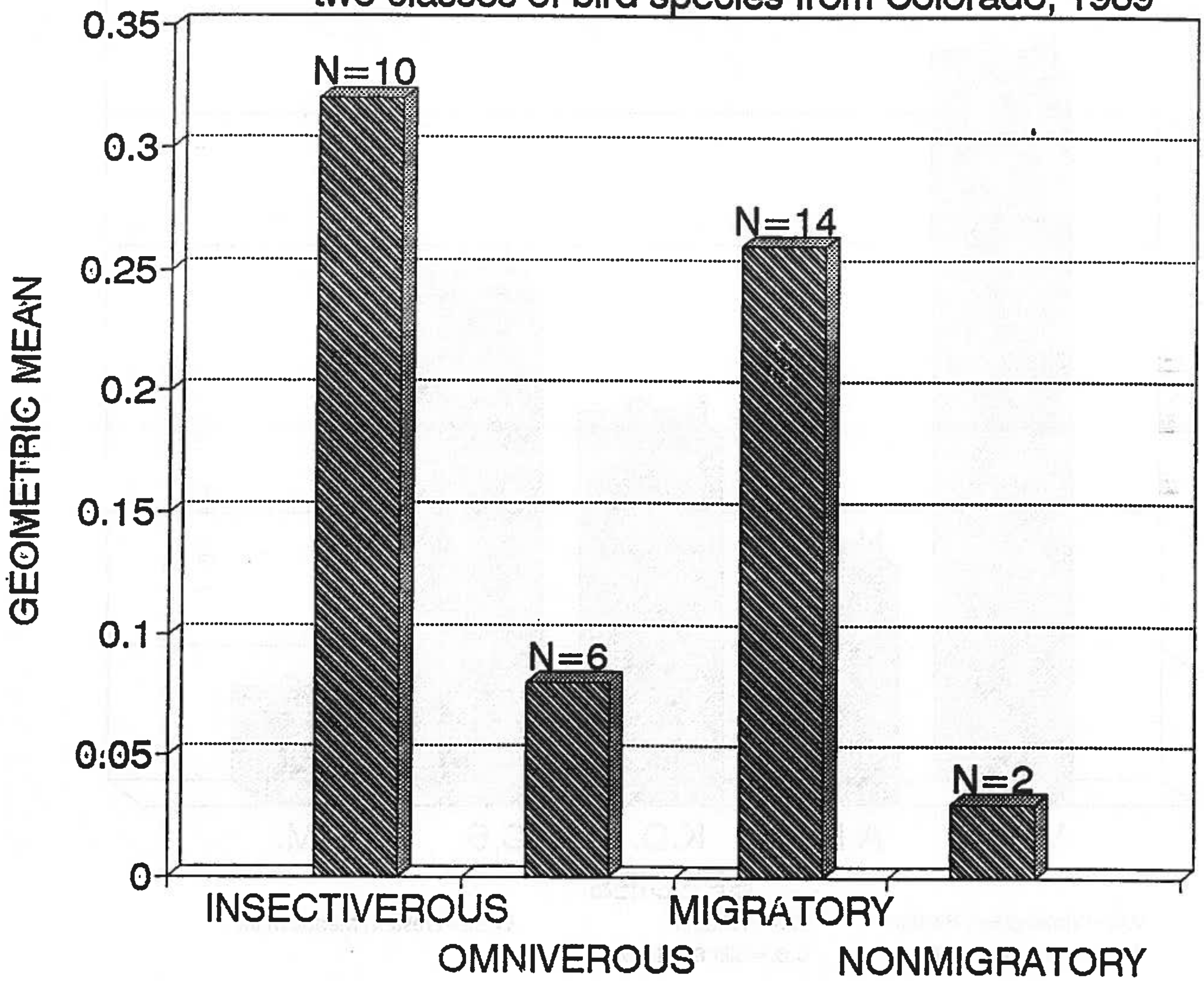
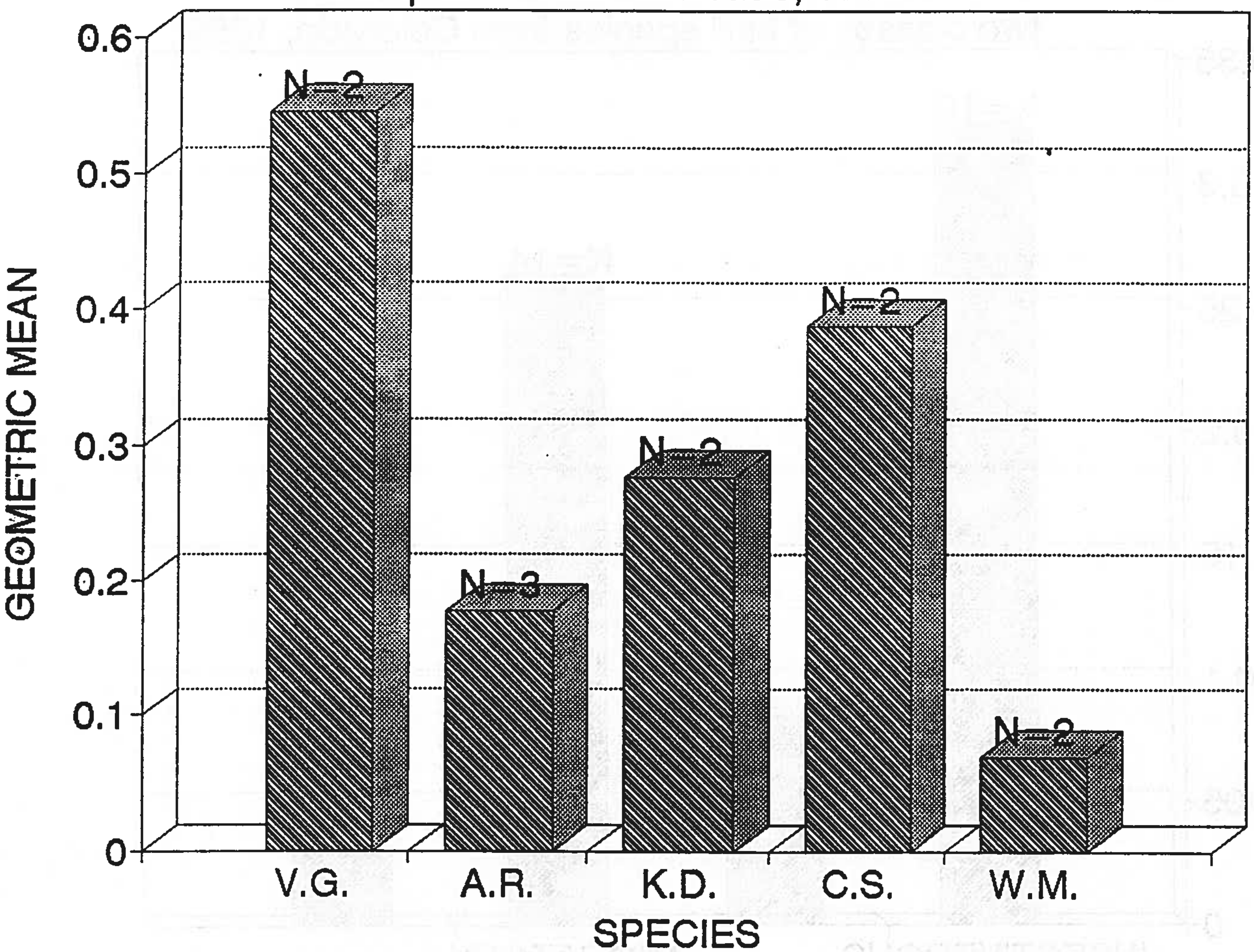


Figure 7. Mercury concentrations in liver samples of selected bird species from Colorado, 1989

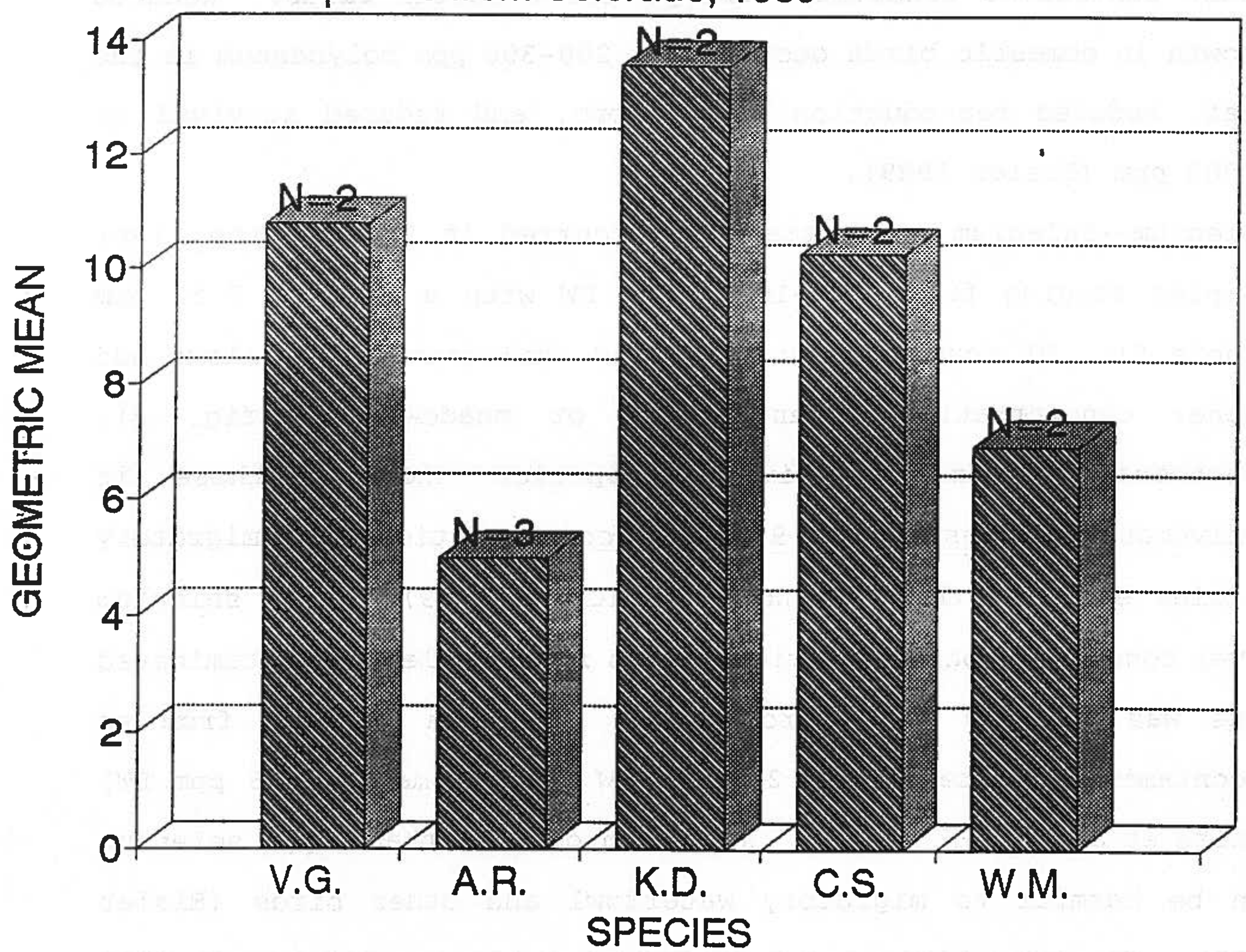


V.G. =Violet-green Swallow
A.R. =American Robin
K.D. =Killdeer
C.S. =Cliff Swallow
W.M. =Western Meadowlark

5). Liver samples taken from American robins collected near a molybdenum mine site had mean concentrations of 1.6 ppm FW (approximately 5.63 ppm DW) (Eisler 1989). However, there is little data on the effects of molybdenum on wild avian species under controlled conditions except for domestic birds. Reduced growth in domestic birds occurred at 200-300 ppm molybdenum in the diet, reduced reproduction at 500 ppm, and reduced survival at 6,000 ppm (Eisler 1989).

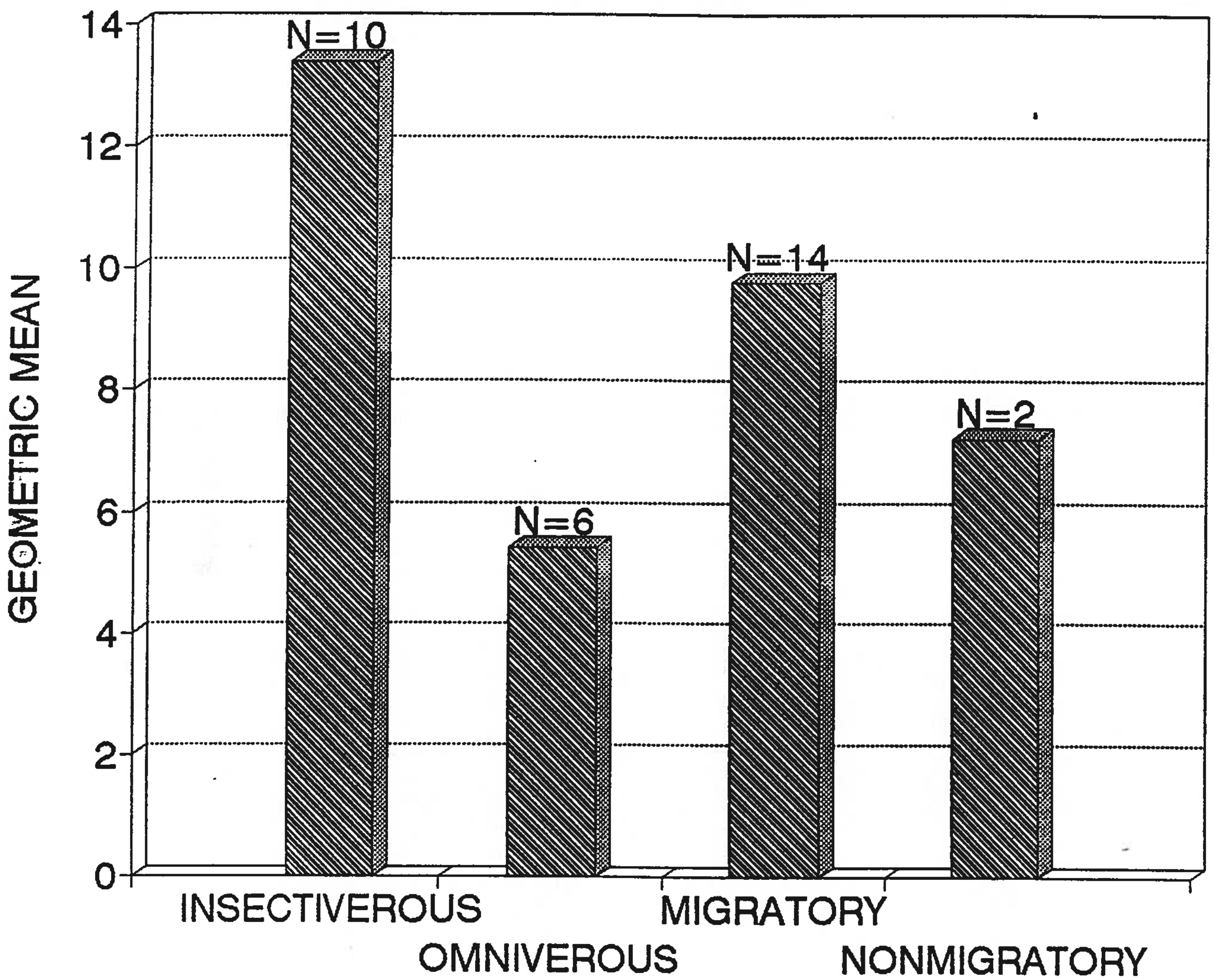
Selenium--Selenium concentrations occurred in 100% of the liver samples ranging from 3.70-19.60 ppm DW with a mean of 9.52 ppm (table 5). Of four species collected, killdeer and swallows had higher concentrations than robins or meadowlarks (fig. 8). Concentrations in insectivorous species exceeded those in omnivorous species (fig. 9), and concentrations in migratory species exceeded those in non-migrants (fig. 9). Mean selenium liver concentrations in American coots from a selenium contaminated site was 2.9 ppm FW (approximately 10.2 ppm DW) and from an uncontaminated site it was 2.5 ppm FW (approximately 8.8 ppm DW) (White et al. 1986). Diets containing greater than 5 ppm selenium can be harmful to migratory waterfowl and other birds (Eisler 1985). The mean liver concentration for birds collected in this study exceeds the 5 mg/kg determined to be harmful in the diet, however, whole birds (the diet of peregrines) would generally have lower concentrations of selenium than liver samples. Because selenium tends to bioaccumulate and biomagnify, peregrine falcons could be exposed to potentially high concentrations of selenium

Figure 8. Selenium concentrations in liver samples of selected species from Colorado, 1989



V.G. =Violet-green Swallow
A.R. =American Robin
K.D. =Killdeer
C.S. =Cliff Swallow
W.M. =Western Meadowlark

Figure 9. Selenium concentrations in liver samples of two classes of bird species from Colorado, 1989



through their prey base, though the data presented here do not warrant such concern. Because little is known about the effects of selenium on avian predators, including the peregrine falcon and because the data presented are insufficient to draw conclusions, it remains unclear whether or not selenium represented in the prey of peregrines could be a concern in some areas.

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APPENDIX A.

Analytical Methods
Quality Assurance/Quality Control

Method 1. **Analysis For Organochlorine Pesticides and PCBs In Animal and Plant Tissue.**

Ten gram tissue samples are thoroughly mixed with anhydrous sodium sulfate and soxhlet extracted with hexane for seven hours. The extract is concentrated by rotary evaporation; transferred to a tared test tube, and further concentrated to dryness for lipid determination. The weighed lipid sample is dissolved in petroleum ether and extracted four times with acetonitrile saturated with petroleum ether. Residues are partitioned into petroleum ether which is washed, concentrated, and transferred to a glass chromatographic column containing 20 grams of Florisil. The column is eluted with 200 ml 6% diethyl ether/94% petroleum ether (Fraction I) followed by 200 ml 15% diethyl ether/85% petroleum ether (Fraction II). Fraction II is concentrated to appropriate volume for quantification of residues by packed or capillary column electron capture gas chromatography. Fraction I is concentrated and transferred to a Silicic acid chromatographic column for additional cleanup required for separation of PCBs from other organochlorines. Three fractions are eluted from the silicic acid column. Each is concentrated to appropriate volume for quantification of residues by packed or megabore column, electron capture gas chromatography. PCBs are found in Fraction II.

B. Florisil Mini-Column:

1. Fraction I (12 ml hexane followed by 12 ml 1% methanol in hexane)
HCB, gamma-BHC (25%), alpha-BHC (splits with FII), trans-nonachlor, o,p'-DDE, p,p'-DDE, o,p'-DDD, p,p'-DDD (splits with FII), o,p'-DDT, p,p'-DDT, mirex, cis-nonachlor, cis-chlordane, trans-chlordane, PCB's, Photomirex and derivatives.

2. Fraction II (24 ml 1% methanol in hexane)
gamma BHC (75%), beta-BHC, alpha-BHC (splits with FI), delta-BHC, oxychlordane, heptachlor epoxide, toxaphene, dicofol, dacthal, endosulfan I, endosulfan II, endosulfan sulfate, octachlorostyrene, Kepone (with additional 12mls 1% methanol in hexane).

C. Silica Gel:

1. SG Fraction I (100 ml petroleum ether)
n-dodecane, n-tridecane, n-tetradecane, ocylcyclohexane, n-pentadecane, nonycyclohexane, n-hexadecane, n-heptadecane, pristane, n-octadecane, phytane, n-nonadecane, n-eicosane.

2. SG Fraction II (100 ml 40% methylene chloride in petroleum ether followed by 50 ml methylene chloride)
napthalene, fluorene, phenanthrene, anthracene, fluoranthrene, pyrene, 1,2-benzanthracene, chrysene, benzo [b] fluoranthrene, benzo [k] fluoranthrene, benzo [e] pyrene, benzo [a] pyrene, 1,2:5,6-dibenzanthracene, benzo

[g,h,i] perylene.

D. Silicic Acid:

1. <u>SA Fraction I</u> (20 ml petroleum ether)

   HCB, mirex

2. <u>SA Fraction II</u> (100ml petroleum ether)

   PCB's, p,p'-DDE (splits with SA III)

3. <u>SA Fraction III</u> (20 ml mixed solvent: 1% acetonitrile, 80% methylene chloride, 19% hexane)

   alpha-BHC, beta-BHC, gamma-BHC, delta-BHC, oxychlordane, heptachlor epoxide, gamma-chlordane, trans-chlordane, toxaphene, o,p'-DDE, alpha-chlordane, p,p'-DDE (splits with SAII), o,p'-DDT, cis-nonachlor, o,p'-DDT, p,p'-DDD, p,p'-DDT, dicofol.

Colo + peregrines

U. S. FISH AND WILDLIFE SERVICE

PATUXENT ANALYTICAL CONTROL FACILITY

QUALITY ASSURANCE REPORT

RE: 6063 REGION: 6 REGIONAL ID: 89-6-068G

THE ANALYSES ON THE ABOVE MENTIONED SAMPLES WERE PERFORMED AT:

THE MISSISSIPPI STATE CHEMICAL LABORATORY
BOX CR
MISSISSIPPI STATE, MISSISSIPPI 39762

AFTER A THOROUGH REVIEW OF THE REPORT ISSUED BY THE LABORATORY, I REPORT THE FOLLOWING OBSERVATIONS AND CONCLUSIONS:

THE ACCURACY, AS MEASURED BY SPIKE RECOVERY, WAS ACCEPTABLE FOR ALL ANALYTES.

THE PRECISION, AS MEASURED BY DUPLICATE SAMPLE ANALYSIS, WAS ACCEPTABLE.

Craig S. Hinke 5-14-90

QUALITY ASSURANCE OFFICER DATE

MAY 18 90

METHODOLOGY

TISSUE SAMPLE PREPARATION

1. **Homogenization.** These were performed using a Kitchen Aid food processor. Portions were then freeze dried for determination of moisture content and subsequent acid digestion.

2. **Preconcentration Digestion for Inductively Coupled Plasma Emission (ICP) Measurement.** Using a CEM microwave oven, 0.5 g of freeze dried tissue are heated in a capped 120 mL Teflon vessel in the presence of 5 mL of Baker Instra-Analyzed nitric acid for three minutes at 120 watts, three minutes at 300 watts, and 35 minutes at 450 watts. The vessel contents are then allowed to cool and the cap is removed and rinsed carefully with 3 mL of HNO_3 adding the rinsings with the vessel contents. The uncapped vessel is then returned to the microwave oven and heated until the vessel contents are less than 1 mL in volume. The contents are carefully rinsed with laboratory pure water into a 10 mL glass volumetric vessel and made to volume with additional laboratory pure water. The flask contents are then immediately transferred to a clean plastic centrifuge or auto sampler tube and centrifuged for 1 minute to precipitate the suspended matter. The sample is now ready for ICP analysis.

3. **Digestion for ICP Measurement.** Using a CEM microwave oven, 0.25 to 0.5 g of freeze dried tissue were heated in a capped 120 mL Teflon vessel in the presence of 5 mL of Baker Instra-Analyzed nitric acid for three minutes at 120 watts, three minutes at 300 watts, and fifteen minutes at 450 watts. The residue was then diluted to 50 mL with 5% HCl.

4. **Digestion for Graphite Furnace Atomic Absorption (GFAA) Measurement.** Using a CEM microwave oven, 0.25 to 0.5 g of freeze dried tissue were heated in a capped 120 mL Teflon vessel in the presence of 5 mL of Baker Instra-Analyzed nitric acid for three minutes at 120 watts, three minutes at 300 watts, and fifteen minutes at 450 watts. The residue was then diluted to 50 mL with laboratory pure water.

5. **Digestion for Hg Measurement by Cold Vapor Atomic Absorption (CVAA).** Some 0.25 to 0.5 g of tissue were refluxed for two hours in 10 mL HNO_3 (Baker Instra-Analyzed) and diluted to 50 mL with 1% HCl.

MEASUREMENT

1. **ICP.** ICP measurements were made using a Leeman Labs Plasma Spec I sequential spectrometer.

2. GFAA. GFAA measurements were made using a Perkin Elmer Zeeman 3030 atomic absorption spectrophotometer with an HGA-600 graphite furnace and an AS-60 autosampler.

3. CVAA. Hg measurements were conducted using $SnCl_4$ as the reducing agent. An Instrumentation Laboratories Model 251 AA spectrophotometer was employed.

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U. S. FISH AND WILDLIFE SERVICE
PATUXENT ANALYTICAL CONTROL FACILITY

QUALITY ASSURANCE REPORT

RE: 6063 REGION: 6 REGIONAL ID: 89-6-068G

THE ANALYSES ON THE ABOVE MENTIONED SAMPLES WERE PERFORMED AT:

THE RESEARCH TRIANGLE INSTITUTE
CORNWALLIS ROAD P.O. BOX 12194
RESEARCH TRIANGLE PARK NC 27709-2194

AFTER A THOROUGH REVIEW OF THE REPORTS ISSUED BY THE LABORATORY, I REPORT THE FOLLOWING OBSERVATIONS AND CONCLUSIONS:

THE ACCURACY, AS MEASURED BY SPIKE RECOVERY AND REFERENCE MATERIAL ANALYSIS, WAS GENERALLY ACCEPTABLE. RECOVERY OF ANTIMONY, SILVER AND TIN BY ICP IS USUALLY LOW AND LITTLE CONFIDENCE CAN BE PLACED IN THE ACCURACY OF THESE ANALYSES. AVERAGE RECOVERY FOR SPIKED SAMPLE ANALYSES IS GIVEN IN TABLE 1.

THE PRECISION, AS MEASURED BY DUPLICATE SAMPLE ANALYSIS, WAS GENERALLY ACCEPTABLE. RECENT SUBMISSIONS FROM THIS LABORATORY HAVE HAD UNUSUALLY HIGH VARIABILITY IN THE ALUMINUM RESULTS. THE ALUMINUM DATA REPORTED HERE SHOULD NOT BE USED. AN ESTIMATE OF THE 95 % CONFIDENCE INTERVAL FOR THE METHODS USED IN THESE ANALYSES IS REPORTED IN TABLE 2.

Clifford P Rice 1-11-90

QUALITY ASSURANCE OFFICER DATE

JAN 17 90

TABLE 1: AVERAGE RECOVERY OF SPIKED ANALYTE FROM SAMPLES ANALYZED BY THE RESEARCH TRIANGLE INSTITUTE USING ATOMIC ABSORPTION

	AVERAGE	STANDARD DEVIATION	NUMBER
MATRIX:TISSUE			
Arsenic	98	7.3	63
Selenium	102	8.9	62
Mercury	96	9.7	72

	AVERAGE	STANDARD DEVIATION	NUMBER
MATRIX:SEDIMENT			
Arsenic	97	7.4	31
Selenium	96	7.9	30
Mercury	98	10.	30

TABLE 2: ESTIMATED 95 % CONFIDENCE INTERVAL FOR ANALYSES PERFORMED BY THE RESEARCH TRIANGLE INSTITUTE USING ATOMIC ABSORPTION

SAMPLE CONCENTRATION*	± CONFIDENCE INTERVAL AS % OF SAMPLE CONCENTRATION 2-10 LOD	>10 LOD
MATRIX:TISSUE	25	15
Arsenic	INS	INS
Selenium	INS	10
Mercury	20	15

SAMPLE CONCENTRATION*	± CONFIDENCE INTERVAL AS % OF SAMPLE CONCENTRATION 2-10 LOD	>10 LOD
MATRIX:SEDIMENT	20	15
Arsenic	INS	INS
Selenium	INS	INS
Mercury	INS	INS

* FOR ANY CONCENTRATION LESS THAN 2 LOD, THE 95 % CONFIDENCE INTERVAL IS ESTIMATED AT ± 2 LOD.

LOD= LIMIT OF DETECTION

INS=INSUFFICIENT DATA TO CALCULATE ON AN INDIVIDUAL ANALYTE BASIS

TABLE 1: AVERAGE RECOVERY OF SPIKED ANALYTE FROM SAMPLES ANALYZED BY THE RESEARCH TRIANGLE INSTITUTE USING ICP (DIRECT)

MATRIX: TISSUE	AVERAGE	STANDARD DEVIATION	NUMBER
Aluminum	98	9.0	42
Antimony	82	13.	30
Barium	98	7.0	56
Beryllium	100	16.	56
Boron	96	7.9	43
Cadmium	101	4.6	56
Cobalt	97	7.4	55
Chromium	99	4.2	56
Copper	101	8.1	55
Iron	101	12.	40
Lead	100	11.	56
Magnesium	100	13.	28
Manganese	100	5.3	52
Molybdenum	102	8.1	44
Nickel	99	5.1	44
Silver	57	36.	53
Strontium	100	14.	43
Tin	69	39.	29
Vanadium	99	5.6	43
Zinc	100	12.	50

MATRIX: SEDIMENT	AVERAGE	STANDARD DEVIATION	NUMBER
Antimony	91	12.	22
Barium	92	17.	6
Beryllium	92	10.	26
Boron	80	28.	25
Cadmium	95	5.9	30
Cobalt	96	8.4	18
Chromium	96	11.	28
Copper	97	11.	30
Lead	96	11.	28
Manganese	90	19.	12
Molybdenum	94	11.	28
Nickel	93	8.0	30
Silver	81	32.	28
Strontium	86	25.	26
Tin	90	25.	27
Vanadium	95	9.4	27
Zinc	98	13.	29

TABLE 2: ESTIMATED 95 % CONFIDENCE INTERVAL FOR ANALYSES PERFORMED BY THE RESEARCH TRIANGLE INSTITUTE USING ICP (DIRECT)

MATRIX: TISSUE

SAMPLE CONCENTRATION*	± CONFIDENCE INTERVAL AS % OF SAMPLE CONCENTRATION 2-10 LOD	>10 LOD
ALL ANALYSES	30	10
Aluminum	INS	INS
Antimony	INS	INS
Barium	INS	20
Beryllium	INS	INS
Boron	INS	INS
Cadmium	INS	INS
Cobalt	INS	INS
Chromium	INS	INS
Copper	30	10
Iron	INS	10
Lead	INS	INS
Magnesium	INS	10
Manganese	INS	15
Molybdenum	INS	INS
Nickel	INS	INS
Silver	INS	INS
Strontium	INS	20
Tin	INS	INS
Vanadium	INS	INS
Zinc	INS	10

* FOR ANY CONCENTRATION LESS THAN 2 LOD, THE 95 % CONFIDENCE INTERVAL IS ESTIMATED AT ± 2 LOD.

LOD= LIMIT OF DETECTION

INS=INSUFFICIENT DATA TO CALCULATE ON AN INDIVIDUAL ANALYTE BASIS

TABLE 1: AVERAGE RECOVERY OF SPIKED ANALYTE FROM SAMPLES ANALYZED BY THE RESEARCH TRIANGLE INSTITUTE USING ICP PRECON(MICROWAVE)

MATRIX: TISSUE	AVERAGE	STANDARD DEVIATION	NUMBER
Aluminum	102	7.2	24
Antimony	85	23.	18
Barium	92	16.	23
Beryllium	100	4.8	24
Boron	92	6.6	24
Cadmium	95	5.8	24
Cobalt	96	6.3	24
Chromium	98	5.3	24
Copper	103	7.8	22
Iron	98	10.	22
Lead	92	12.	24
Magnesium	99	7.7	12
Manganese	99	9.3	23
Molybdenum	100	6.8	24
Nickel	97	4.4	24
Silver	58	28.	24
Strontium	102	11.	22
Tin	74	25.	18
Vanadium	99	4.5	24
Zinc	103	7.2	16

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TABLE 2: ESTIMATED 95 % CONFIDENCE INTERVAL FOR ANALYSES PERFORMED BY THE RESEARCH TRIANGLE INSTITUTE USING ICP PRECON (MICROWAVE)

MATRIX: TISSUE

	± CONFIDENCE INTERVAL AS % OF SAMPLE CONCENTRATION	
SAMPLE CONCENTRATION*	2-10 LOD	>10 LOD
ALL ANALYSES	40	20
Aluminum	INS	INS
Antimony	INS	INS
Barium	INS	INS
Beryllium	INS	INS
Boron	INS	INS
Cadmium	INS	INS
Cobalt	INS	INS
Chromium	INS	INS
Copper	INS	INS
Iron	INS	20
Lead	INS	INS
Magnesium	INS	15
Manganese	INS	10
Molybdenum	INS	INS
Nickel	INS	INS
Silver	INS	INS
Strontium	INS	INS
Tin	INS	INS
Vanadium	INS	INS
Zinc	INS	10

* FOR ANY CONCENTRATION LESS THAN 2 LOD, THE 95 % CONFIDENCE INTERVAL IS ESTIMATED AT ± 2 LOD.

LOD= LIMIT OF DETECTION

INS=INSUFFICIENT DATA TO CALCULATE ON AN INDIVIDUAL ANALYTE BASIS

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DEPARTMENT OF INTERIOR

FISH AND WILDLIFE SERVICE

Contract No. 14-16-0009-87-00 (RTI No. 432U-3907)

Catalog 6063

Animal Tissue Sample Analysis/ICP

QC/QA

Detection Limits

Duplicate Sample Analyses

Spike Analyses

SRM Sample Analyses

Method Blank Analyses

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QC/QA--Duplicate Sample Analyses

Animal Tissue - ICP

Results in µg/g (dry weight)

Element	BC-A-8L Sample	BC-A-8L Dup.	RH-ML-2L Sample	RH-ML-2L Dup.	------ Sample	------ Dup.	------ Sample	------ Dup.
Al	<30	<30	<30	<30				
Sb	<30	<30	<30	<30				
Ba	<1.0	<1.0	<1.0	<1.0				
Be	<0.3	<0.3	<0.3	<0.3				
B	3.02	3.26	<3.0	<3.0				
Cd	1.76	1.92	<0.6	<0.6				
Co	<2.5	<2.5	<2.5	<2.5				
Cr	<3.0	<3.0	<3.0	<3.0				
Cu	18.9	16.7	142	150				
Fe	3070	3130	1970	1940				
Pb	<5.5	<5.5	<5.5	<5.5				
Mg	878	921	720	722				
Mn	6.65	6.26	12.0	14.1				
Mo	<5.0	<5.0	<5.0	<5.0				
Ni	<5.0	<5.0	<5.0	<5.0				
Ag	<15	<15	<15	<15				
Sr	<2.0	<2.0	<2.0	<2.0				
Sn	<30	<30	<30	<30				
V	<2.5	<2.5	<2.5	<2.5				
Zn	85.0	87.5	104	104				

QC/QA--Spike Analyses
Animal Tissue - ICP

Results in µg/mL

Element	FX-A-1L Expec.	Found	% Rec.	Unspiked Sample	PR-A-3L (Sb,Sn) Expec.	Found	% Rec.	Unspiked Sample
Al	20.0	20.6	103	<0.05				
Sb	no spike				4.00	4.11	103	<0.05
Ba	2.02	2.04	101	<0.01				
Be	2.00	2.13	107	<0.01				
B	2.02	2.15	106	0.02				
Co	2.04	2.14	105	<0.01				
Cd	2.00	2.07	104	0.03				
Cr	2.02	2.05	101	<0.01				
Cu	2.06	2.16	105	0.19				
Fe	20.0	19.4	97.0	17.7				
Pb	10.0	10.5	105	<0.05				
Mg	20.0	20.2	101	9.49				
Mn	2.04	2.20	108	0.06				
Mo	1.00	1.09	109	0.04				
Ni	10.0	10.4	106	<0.01				
Ag	0.100	0.019	19.0	<0.01				
Sr	2.00	2.05	103	<0.01				
Sn	no spike				4.00	3.61	90.3	<0.05
V	2.00	2.11	106	<0.01				
Zn	2.04	2.08	102	1.00				

QC/QA--Spike Analyses

Animal Tissue - ICP

Results in µg/mL

Element	RH-H-3L Expec.	RH-H-3L Found	% Rec.	Unspiked Sample	RH-CG-5L (Sb, Sn) Expec.	RH-CG-5L (Sb, Sn) Found	% Rec.	Unspiked Sample
Al	20.0	20.9	105	<0.05				
Sb		no spike			4.00	3.65	91.3	<0.05
Ba	2.02	2.07	102	<0.01				
Be	2.00	2.03	102	<0.01				
B	2.02	2.11	104	0.03				
Co	2.04	2.16	106	<0.01				
Cd	2.00	2.14	107	<0.01				
Cr	2.02	2.13	105	0.02				
Cu	2.06	1.98	96.1	0.98				
Fe	20.0	19.4	97.0	17.0				
Pb	10.0	10.3	103	<0.05				
Mg	20.0	20.6	103	8.11				
Mn	2.04	2.14	105	0.12				
Mo	1.00	1.07	107	0.04				
Ni	10.0	10.6	106	0.01				
Ag	0.100	0.097	97.0	<0.01				
Sr	2.00	2.12	106	<0.01				
Sn		no spike			4.00	3.24	81.0	<0.05
V	2.00	2.10	105	<0.01				
Zn	2.04	2.15	105	1.08				

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QC/QA--SRM Sample Analyses
Animal Tissue - ICP

Results in µg/g (dry weight)

Element	TORT-1		DORM-1		-----		-----	
	Expec.	Found	Expec.	Found	Expec.	Found	Expec.	Found
Al	---	<30	---	<30				
Sb	---	<30	---	<30				
Ba	---	3.98	---	<1.0				
Be	---	<0.3	---	<0.3				
B	---	5.97	---	<3.0				
Cd	26.3	26.6	0.086	<0.6				
Co	0.42	<2.5	0.049	<2.5				
Cr	2.4	<3.0	3.60	<3.0				
Cu	439	483	5.22	4.64				
Fe	186	181	63.6	59.5				
Pb	10.4	10.7	0.40	<5.5				
Mg	2550	2560	1210	1250				
Mn	23.4	24.2	1.32	<2.0				
Mo	1.5	<5.0	---	<5.0				
Ni	2.3	<5.0	1.20	<5.0				
Ag	---	<15	---	<15				
Sr	113	114	---	7.64				
Sn	---	<30	---	<30				
V	1.4	<2.5	--	<2.5				
Zn	177	168	21.3	18.9				

Method Blank Analyses
Animal Tissue - ICP

Results in µg/g (dry weight)

Element	Sample Number					
	1	2	-----	-----	-----	-----
Al	<30	<30				
Sb	<30	<30				
Ba	<1.0	<1.0				
Be	<0.3	<0.3				
B	<3.0	<3.0				
Cd	<0.6	<0.6				
Co	<2.5	<2.5				
Cr	<3.0	<3.0				
Cu	<4.6	<4.6				
Fe	<50	<50				
Pb	<5.5	<5.5				
Mg	<50	<50				
Mn	<2.0	<2.0				
Mo	<5.0	<5.0				
Ni	<5.0	<5.0				
Ag	<15	<15				
Sr	<2.0	<2.0				
Sn	<30	<30				
V	<2.5	<2.5				
Zn	<5.0	<5.0				

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DEPARTMENT OF INTERIOR

FISH AND WILDLIFE SERVICE

Contract No. 14-16-0009-87-00 (RTI No. 432U-3907)

Catalog 6063

Animal Tissue Sample Analysis/AA

QC/QA

Duplicate Sample Analyses

Spike Analyses

SRM Sample Analyses

Method Blank Analyses

QC/QA--Duplicate Sample Analyses
Tissue - AA

Results in µg/g (dry weight)

Element	BC-A-8L Sample	BC-A-8L Dup.	RH-ML-2L Sample	RH-ML-2L Dup.	----- Sample	----- Dup.	----- Sample	----- Dup.
As	<0.2	<0.2	<0.2	<0.2				
Pb	0.751	0.562	0.608	0.677				
Hg(CV)	0.124	0.128	1.83	1.78				
Se	4.20	4.60	12.2	12.2				

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QC/QA--Spike Analyses
Animal Tissue - AA

Results in µg/mL

Element	FX-A-1L				RH-H-3L			
	Expec.	Found	% Rec.	Unspiked Sample	Expec.	Found	% Rec.	Unspiked Sample
As	0.200	0.248	124	0.014	0.200	0.236	118	<0.002
Pb	---	---	---	---	0.200	0.212	106	0.0043
Hg(CV)	0.0200	0.0222	111	0.00320	0.0200	0.0224	112	0.00740
Se	0.200	0.188	94.0	0.0784	0.200	0.181	90.5	0.0721

Element	LM-ML-40				RH-ML-2L			
	Expec.	Found	% Rec.	Unspiked Sample	Expec.	Found	% Rec.	Unspiked Sample
As	0.200	0.210	105	<0.002	---	---	---	---
Pb	---	---	---	---	0.200	0.208	104	0.0064
Hg(CV)	0.0200	0.0220	110	<0.0002	---	---	---	---
Se	0.200	0.205	102	0.245	---	---	---	---

QC/QA--SRM Sample Analyses
Animal Tissue - AA

Results in $\mu g/g$ (dry weight)

Element	TORT-1 Expec.	TORT-1 Found	DORM-1 Expec.	DORM-1 Found	NIST 1577a Expec.	NIST 1577a Found	----- Expec.	----- Found
As	24.6	27.3	17.7	16.1	0.047	<0.2		
Pb	10.4	9.90	0.4	1.10	0.135	<0.4		
Hg(CV)	0.33	0.278	0.798	0.790	0.004	<0.02		
Se	6.88	6.98	1.62	1.44	0.71	0.504		

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Method Blank Analyses
Animal Tissue - AA

Results in µg/g (dry weight)

Element	Sample Number					
	1	2	------	------	------	------
As	<0.2	<0.2				
Pb	<0.2	<0.2				
Hg(CV)	<0.02	<0.02				
Se	<0.3	<0.3				

APPENDIX B.

Analytical Results
Organochlorines

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Results of Organochlorine Analysis of Liver Samples Taken From Birds Collected in Colorado, 1989

SPECIES COMMON NAME	SAMPLE ID	COMPOUND % Moisture	% Lipid	HCB	Alpha-BHC	Beta-BHC	Oxychlordane
Violet-green Swallow	BC-V-7	68.0	9.22	ND	ND	0.01	0.02
Tree Swallow	BC-T-9	68.5	9.00	ND	ND	0.04	0.03
American Robin	BC-A-8	71.5	4.18	ND	ND	ND	ND
Tree Swallow	PR-T-4	63.5	8.12	ND	ND	0.03	0.02
American Robin	FX-A-1	72.5	3.82	ND	ND	ND	ND
Barn Swallow	CM-S-10	64.0	10.70	ND	ND	ND	0.01
American Robin	PR-A-3	74.5	3.78	ND	ND	ND	ND
Killdeer	CM-K-11	70.0	7.00	ND	ND	ND	0.01
Cliff Swallow	CM-C-12	61.0	16.30	ND	ND	0.02	0.02
Western Meadowlark	CM-L-14	72.0	3.40	ND	ND	ND	ND
Red-winged Blackbird	CM-R-13	72.5	3.36	ND	ND	ND	ND
Violet-green Swallow	CM-V-15	65.0	8.38	ND	ND	0.01	0.01
Red-winged Blackbird	MV-R-16	73.0	3.50	ND	ND	ND	ND
Violet-green Swallow	MV-V-17	65.0	10.40	ND	ND	ND	0.01
Killdeer	MV-K-18	71.0	5.12	ND	ND	ND	ND
Cliff Swallow	MV-C-19	68.0	11.00	ND	ND	ND	ND
Spotted Sandpiper	PR-P-5	67.0	7.10	ND	ND	ND	ND
Tree Swallow	DM-T-20	64.0	12.10	0.01	0.01	0.23	0.05
Western Meadowlark	DM-L-21	71.5	3.72	ND	ND	0.01	ND
Brew Blackbird	DM-B-22	71.0	4.06	0.03	ND	0.01	0.03
White-throated Swift	DM-W-23	64.5	11.10	0.01	0.01	0.04	0.01
Killdeer	DM-K-24	67.5	8.70	ND	ND	0.02	0.02
Tree Swallow	CS-T-25	68.0	4.80	ND	ND	0.02	0.02
American Robin	CS-A-26	71.0	3.30	ND	ND	ND	ND
Violet-green Swallow	RG-V-27	68.0	9.01	ND	ND	ND	ND

SPECIES COMMON NAME	SAMPLE ID	COMPOUND Heptachlor Epoxide	t-Nonachlor	PCB's (total)	Alpha-Chlordane	DDE	Dieldrin	Mirex
Violet-green Swallow	BC-V-7	0.02	0.01	0.13	ND	0.81	0.01	ND
Tree Swallow	BC-T-9	0.02	ND	0.33	ND	4.3	0.04	ND
American Robin	BC-A-8	ND	ND	ND	ND	0.09	ND	ND
Tree Swallow	PR-T-4	0.01	ND	0.46	ND	3.3	ND	ND
American Robin	FX-A-1	ND	ND	ND	ND	0.06	ND	ND
Barn Swallow	CM-S-10	0.01	ND	0.14	ND	0.91	0.01	ND
American Robin	PR-A-3	ND	ND	ND	ND	0.02	ND	ND
Killdeer	CM-K-11	0.03	0.01	0.12	ND	2.6	0.04	ND
Cliff Swallow	CM-C-12	0.01	ND	0.26	ND	1.3	ND	0.1
Western Meadowlark	CM-L-14	ND	ND	ND	ND	0.37	ND	ND
Red-winged Blackbird	CM-R-13	ND	ND	ND	ND	0.1	ND	ND
Violet-green Swallow	CM-V-15	0.02	ND	ND	ND	0.39	0.01	ND
Red-winged Blackbird	MV-R-16	ND	ND	ND	ND	0.02	ND	ND
Violet-green Swallow	MV-V-17	ND	ND	0.16	ND	1.3	ND	ND
Killdeer	MV-K-18	ND	ND	ND	ND	1.4	ND	ND
Cliff Swallow	MV-C-19	ND	ND	ND	ND	1.4	ND	0.17
Spotted Sandpiper	PR-P-5	ND	ND	ND	ND	0.34	ND	ND
Tree Swallow	DM-T-20	0.05	0.01	0.41	0.03	4.2	0.05	ND
Western Meadowlark	DM-L-21	ND	ND	ND	ND	3.3	0.02	ND
Brew Blackbird	DM-B-22	0.06	0.01	ND	ND	2.7	0.02	ND
White-throated Swift	DM-W-23	0.01	0.01	ND	ND	1.3	0.02	ND
Killdeer	DM-K-24	0.01	0.01	0.37	ND	4.6	0.06	ND
Tree Swallow	CS-T-25	ND	ND	ND	ND	1.1	ND	ND
American Robin	CS-A-26	ND	ND	ND	ND	0.03	ND	ND
Violet-green Swallow	RG-V-27	ND	ND	ND	ND	0.98	ND	ND

APPENDIX C.

Analytical Results
Trace Elements

Results of Trace Element Analysis of Liver Samples Taken From Birds Collected in Colorado, 1989

SPECIES COMMON NAME	SAMPLE I.D.	% MOIST.	Al	As	Ba	Be	B
			ELEMENT				
American Robin	BC-A-8L	71.5	10.80	<0.2	0.435	<0.050	3.300
American Robin	FX-A-1L	75.3	<6.00	1.290	0.238	<0.050	1.620
Barn Swallow	CM-S-10L	68.9	<6.00	<0.2	0.234	0.057	1.250
American Robin	PR-A-3L	72.1	<6.00	0.238	<0.200	<0.050	2.050
Killdeer	CM-K-11L	70	18.40	<0.2	0.438	<0.050	0.981
Cliff Swallow	CM-C-12L	69.2	<6.00	<0.2	<0.200	<0.050	1.120
Meadowlark	CM-L-14L	75.5	<6.00	<0.2	<0.200	<0.050	1.610
Red-Winged Blackbird	CM-R-13L	68.6	11.90	0.229	0.231	<0.050	1.460
Violet-Green Swallow	CR-V-15L	68.2	<6.00	<0.2	<0.200	<0.050	1.440
Violet-Green Swallow	MV-V-17L	70.1	<6.00	<0.2	<0.200	<0.050	1.400
Cliff Swallow	MV-C-19L	70.8	6.65	<0.2	<0.200	<0.050	1.440
Tree Swallow	DM-T-20L	83.2	11.20	<0.2	0.203	<0.050	0.977
Meadowlark	DM-L-21L	72	<6.00	<0.2	<0.200	0.053	1.590
Brewers Blackbird	DM-B-22L	69	<6.00	<0.2	<0.200	<0.050	1.170
White-Throated Swift	DM-W-23L	71.7	<6.00	<0.2	<0.200	<0.050	0.75[illegible]
Killdeer	DM-K-24L	69.8	8.75	<0.2	0.500	<0.050	0.966

SPECIES COMMON NAME	SAMPLE I.D.	Cd	Cr	Cu	Fe	Mg	Mn
		ELEMENT					
American Robin	BC-A-8L	1.660	<0.500	19.600	2990.000	903.000	5.630
American Robin	FX-A-1L	2.920	<0.500	18.800	1620.000	886.000	5.960
Barn Swallow	CM-S-10L	0.966	<0.500	19.500	662.000	829.000	3.730
American Robin	PR-A-3L	1.860	<0.500	18.100	1830.000	943.000	4.680
Killdeer	CM-K-11L	2.740	0.624	23.000	670.000	839.000	15.500
Cliff Swallow	CM-C-12L	1.500	<0.500	21.000	927.000	900.000	6.040
Meadowlark	CM-L-14L	1.810	0.649	25.200	1140.000	859.000	5.140
Red-Winged Blackbird	CM-R-13L	1.110	0.572	23.600	1130.000	854.000	5.230
Violet-Green Swallow	CR-V-15L	1.600	0.630	23.500	860.000	843.000	6.570
Violet-Green Swallow	MV-V-17L	1.060	1.340	23.100	655.000	862.000	5.590
Cliff Swallow	MV-C-19L	1.120	0.821	20.900	1080.000	913.000	7.490
Tree Swallow	DM-T-20L	1.170	0.672	20.400	650.000	783.000	4.750
Meadowlark	DM-L-21L	1.100	0.794	20.600	1360.000	921.000	6.540
Brewers Blackbird	DM-B-22L	0.405	0.662	19.300	940.000	769.000	5.570
White-Throated Swift	DM-W-23L	3.410	<0.500	23.000	687.000	705.000	13.600
Killdeer	DM-K-24L	1.070	0.730	22.600	732.000	714.000	14.700

SPECIES COMMON NAME	SAMPLE I.D.	ELEMENT Hg	Mo	Pb	Se	Sr	Zn
American Robin	BC-A-8L	0.124	4.280	0.751	4.200	<0.300	81.400
American Robin	FX-A-1L	0.304	5.150	0.884	7.450	<0.300	89.700
Barn Swallow	CM-S-10L	0.242	3.240	0.345	19.600	0.460	75.700
American Robin	PR-A-3L	0.140	3.180	0.724	4.180	0.305	89.400
Killdeer	CM-K-11L	0.126	2.890	0.534	16.700	0.762	86.400
Cliff Swallow	CM-C-12L	0.524	3.340	0.229	18.900	<0.300	97.100
Meadowlark	CM-L-14L	0.072	3.140	1.280	12.800	0.915	87.200
Red-Winged Blackbird	CM-R-13L	<0.02	2.500	0.238	13.800	0.753	78.300
Violet-Green Swallow	CR-V-15L	0.331	2.530	0.692	8.750	<0.300	80.600
Violet-Green Swallow	MV-V-17L	0.898	2.000	<0.2	13.300	<0.300	94.500
Cliff Swallow	MV-C-19L	0.286	2.590	0.295	5.590	0.402	98.100
Tree Swallow	DM-T-20L	0.403	2.610	0.295	18.600	0.300	[illegible]
Meadowlark	DM-L-21L	0.065	3.150	0.487	3.770	<0.300	85.000
Brewers Blackbird	DM-B-22L	0.099	3.320	<0.2	3.700	<0.300	79.000
White-Throated Swift	DM-W-23L	0.472	1.620	<0.2	17.200	<0.300	82.400
Killdeer	DM-K-24L	0.608	2.650	0.238	11.000	0.424	75.600

* concentrations for Ag, Co, Ni, Sn, and V were less than detection limit for all samples